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IRRIGATION OF ALFALFA

THERE are several methods of applying water to alfalfa, their suitability depending on character of soil and subsoil, climate, water supply, size of farm, money available, and other factors.

Because of the rapidity of its growth and the number of cuttings during the season, alfalfa requires more water than other crops. This may lead to carelessness and the consequent application of too much water, which must be avoided.

No fixed times can be recommended for watering the crop. The appearance of the alfalfa, more particularly the color of the plant, is the best indication of the need of water.

This bulletin is written for the purpose of putting the farmer in a better position to understand the proper methods to adopt in building ditches on his farm and in applying water to his crops.

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IRRIGATION OF ALFALFA.

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CONTENTS.

ALFALFA ADAPTED TO ARID AND SEMIARID REGIONS.

EXPERIENCE in the growing of alfalfa for more than two thousand years shows that it thrives best in the soil and climate of arid and semiarid regions. The abundant sunshine, the warmth, and the deep, rich soil prevailing throughout the western half of the United States seem to be well suited to its requirements, and more than half a century's experience has shown that there is comparatively little cultivatable land in the West on which it can not be grown, except where the soil has become sour or waterlogged, where it is impregnated with alkali, or where hardpan is found near the surface. One finds the same varieties flourishing in Imperial Valley, California, 100 feet below sea level, and maintaining a sturdy growth on the San Luis plains of Colorado, 7,500 feet higher. Alfalfa makes a remarkable growth in the warm sunshine of Arizona, yet it is rarely injured by cold in Montana.

METHODS OF IRRIGATING ALFALFA.

The methods of applying water to alfalfa differ widely because of diversity in soils and subsoils, in climate and topography, in the nature of the water supply, the size of the farm, the amount of money available for preparing the land for water, the prevailing crops grown, and the early training and environment of the irrigator. The standard methods have been grouped under the following heads, namely, the border method, the check method, flooding from field laterals, furrow irrigation, and other less common methods, with various modifications of each.

In passing it may be said that the usual order is to locate and build the farm ditches first and prepare the land afterwards. In this bulletin it has been deemed best to describe the methods in use and then to consider the location and construction of farm ditches. After one has a general knowledge of the various ways of applying water and

of the size and character of the ditches required for each method he is in a better position to understand the proper methods to adopt in building farm ditches.

THE BORDER METHOD.

Essentially the border method consists of the division of a field or tract into long, narrow strips or lands by low, flat levees, which usually extend in the direction of the steepest slope, if this is not so great as to cause washing of the soil or difficulty in spreading water, and confine the water to a single strip (fig. 1). The bed of each strip is carefully graded to a uniform slope. If it is necessary to change the slope to conform to the contour of the natural surface, an additional head ditch should be placed at each change in slope.

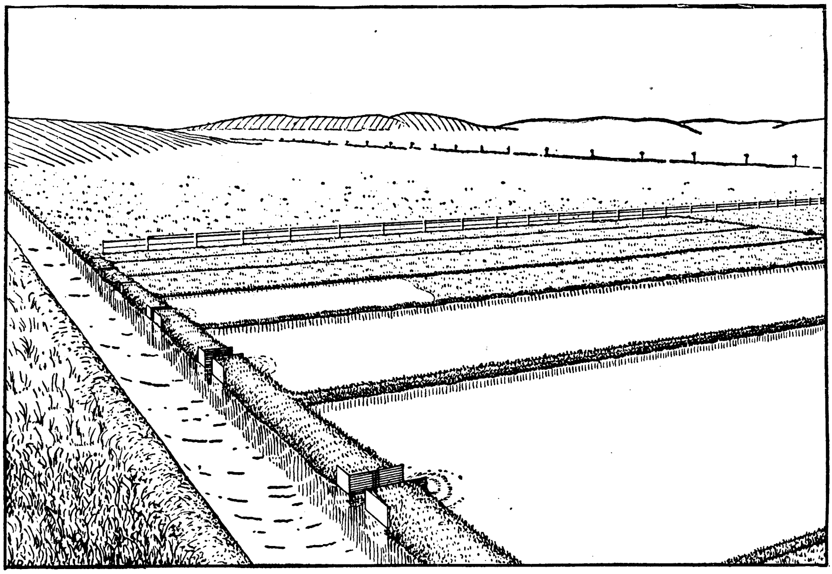

FIG. 1.—Sketch showing head ditch and border method of irrigation.

The water to irrigate each strip is taken from the head ditch extending across the upper edge of the field and is controlled by an outlet box or border gate, although the gates are sometimes omitted to save in first cost of preparing for irrigation where the soil is not so light as to induce excessive washing. Check gates, canvas dams, or metal tappoons are used to hold up the water in the head ditch to cause it to flow into the borders. In many sections these temporary makeshifts are giving way to permanent structures. The best width of the strips between levees depends upon the size of the stream of water available for irrigation, the slope of the land, and the porosity of the soil.

This method is confined chiefly to the irrigation of alfalfa and grain, and in its various modifications is used extensively in Arizona,

New Mexico, California, and, to a less extent, in Idaho, Montana, and other Rocky Mountain States. It can be used best under canals which deliver water to users in large streams, since the smallest head that can be applied successfully is seldom less than 2 or 3 cubic feet per second, while heads of 5 to 10 cubic feet per second are common. It is adapted especially to light, open soils, into which water percolates rapidly, as the use of a large stream confined between borders makes it possible to force water over the surface without great loss by percolation, but is not well adapted to very gravelly soils.

On the university farm at Davis, Calif., the borders or lands formerly averaged about 50 feet wide by 900 feet long, but in recent years the widths have been reduced to 35 and 40 feet and the lengths to about 600 feet. Each levee has a base 7 feet wide and is 12 inches high, when newly made, but settles to about 10 inches before the first crop is harvested. The bed of each strip is leveled crosswise and slopes regularly from top to bottom. In preparing the surface of this field the barley stubble was burned, then the soil was disked and roughly graded. The location of each border was marked out either

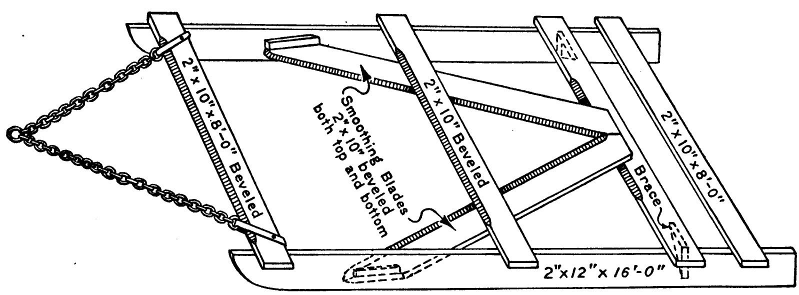

FIG. 2.—Levee smoother.

by a drag or by making a furrow. Sufficient earth to form the border was obtained by skimming the surface with scrapers. The scraper teams began next to the head ditch and worked down. They crossed and recrossed the field at right angles to the borders, and as a scraper passed a border marking it was dumped. Each scraper width of the borders was made up of two loads, but the last load overlapped the first by half the width of the scraper. The surface of each border was then leveled to within 0.1 or 0.2 foot of accuracy. The levees when first built were rough, irregular, and steep. They were cut down to a uniform grade by a homemade device called a planer, or levee smoother, shown in Figure 2.

In Imperial Valley, Calif., a 40-acre tract is divided in 22 lands each 60 feet wide and 0.25 mile long. In order to lessen the first cost, the material for the levees, instead of being scraped from the high portions of the lands, is taken from the sides of these levees. This creates hollows in which water may collect, thus lessening the amount received by the rest of the land, makes the mowing and

raking more difficult, and frequently lessens the yield. Such levees may be made by the use of the plow and ridger (fig. 3). In this method a narrow strip is first plowed and then the ridger, drawn by a number of horses, forms the loose earth into a ridge. The cost per acre for preparing the land by the border method in this valley varies all the way from $8 to $30, depending on the character of the native vegetation and the size and number of the hummocks. When creosote bushes and mesquite trees are surrounded by wind-driven sands, the cost may run as high as $50 to $75 per acre.

In Salt River Valley, Ariz., and in New Mexico the customary method of preparing the land for alfalfa is to remove the brush, plow the high places, and roughly level the surface with suitable scrapers. Then the borders are marked off from 30 to 50 feet apart. The spacing depends on the porosity of the soil, the configuration of the land, and the head of water available. After forming rough borders by means of four plow furrows thrown together to form a ridge, a disk or spring-tooth harrow is run lengthwise of the lands. The borders are then crowded with a V crowder and usually a leveler is run transversely to the borders to round them off. The land then receives a heavy irrigation and when dry enough to work is again disked or harrowed and seeded. Such borders when first made have a base of about 3 feet and a height of 1 foot, which settles to about 9 inches. The length of the borders or lands varies from one-eighth to one-half mile, although the tendency is to make them shorter.

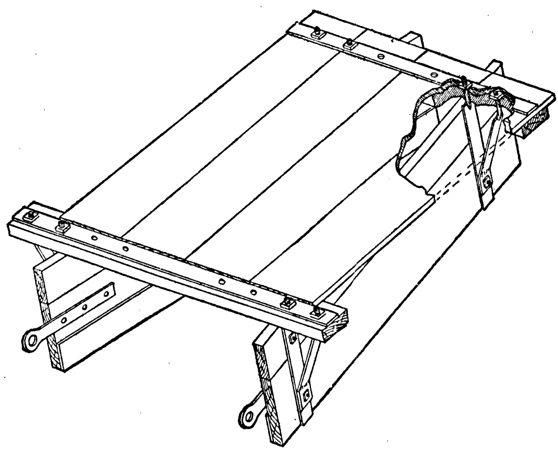

Fig. 3.—Adjustable ridger.

The farmers on the Roswell Bench on the south side of the Boise River in Idaho make the levees 66 feet apart and 300 to 1,300 feet long, depending chiefly on the topography of the land. The land is first leveled with scrapers, then plowed and harrowed, after which the borders are marked off and thrown up by plowing two to four furrows with a heavy plow. Before seeding, a homemade planer is dragged lengthwise and crosswise of the lands in order to fill up the hollows by cutting off the high places. The cost of preparing land in this way and seeding varies from $15 to $50 per acre, depending upon the roughness of the surface.

One of the great advantages of this method is that it enables one man to use a large stream of water and irrigate a large area with a minimum of labor. In the Salt River Valley, Ariz., the irrigation heads delivered vary from 300 to 400 Arizona miner's inches. This stream is divided into two to four heads, and turned into as many

lands, depending on the size of the lands. One man can handle a stream of this size. The size of streams used in the Rillito Valley in Arizona varies. A head of about 100 miner's inches is turned into a plat of land 30 feet wide and takes one to three hours to reach the lower end, 660 feet distant. Two men working 12 hours each, with this head of water, will irrigate in 24 hours 12 to 15 acres, at a cost of 30 to 50 cents per acre for each watering. In the Santa Cruz Valley and elsewhere in Arizona the tendency is to use smaller lands and smaller heads with a view to greater economy in water. The average rate of irrigation in Arizona is from one-half to one acre per hour with a head of 80 miner's inches or 2 second-feet delivered to each land. In the extensive alfalfa fields belonging to the Butterfield Live Stock Co., of Weiser, Idaho, the head ditch has a capacity of 150 to 500 miner's inches, divided into three or four streams, and permitted to flow down as many lands until the soil is moistened to a depth of several feet. Each field receives three such waterings in a season. On the alfalfa fields in Yolo County, Calif., the natural slope of the land is about 1 foot in 400. On the shorter lands the head used is seldom less than 6 cubic feet per second, but three and four times this quantity is often applied to the longer lands. On fields well laid off, with good border gates and border levees, two men can irrigate 20 to 40 acres in 12 hours, the area within these limits depending chiefly on the size of the irrigating head. In Imperial Valley, Calif., the size of the head used varies from 50 to 600 miner's inches, but the present tendency is toward the use of the smaller heads. In using a head of 500 inches it is customary to divide it among five lands. With such a head it is not unusual for two men working 12-hour shifts to irrigate 80 acres in 24 hours.

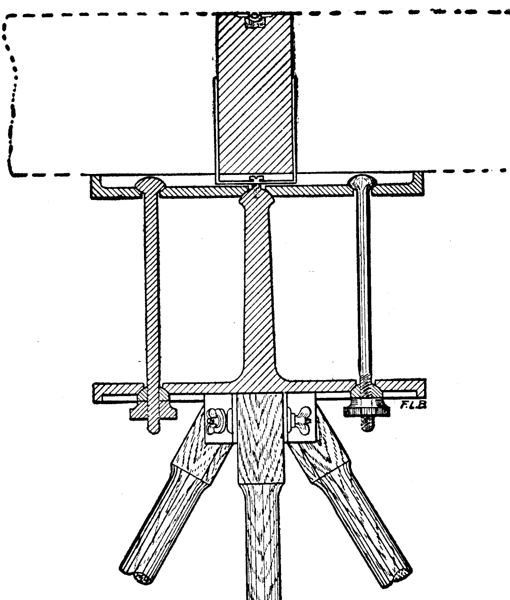

FIG. 4.—Carpenter's spirit level attached to a tripod.

THE CHECK METHOD.

The essential features of the check method of irrigation consist in surrounding nearly level plats of ground with low levees, and in making provision to flood each by means of a ditch and check box or gate. The inclosed spaces may be laid out in straight lines in both directions, thus forming with their levee borders a series of rectangles, or the levees may follow more or less closely the contour

lines of the natural surface of the ground, thus forming contour checks. The most favorable conditions are a light, sandy soil on a comparatively even slope of 3 to 15 feet to the mile, abundantly supplied with water. This method is used also on heavy soils, where it is necessary to hold the water on the soil to secure its percolation to the desired depth.

In California not only does the form of the checks vary, but their size as well, some of the smaller being less than one-half acre in area, while some of the larger contain more than 10 acres.

In the Modesto and Turlock irrigation districts the surface of the land under ditch slopes about 5 feet to the mile, and is too uneven to be irrigated without being leveled first. The unevenness consists in swales, hog wallows, and mounds. The land is surveyed first either by an engineer or by the owner. In the latter case use is made of a carpenter's level, with peep sights, mounted on a tripod (fig. 4). The long side of each check should be on the flat slope and the

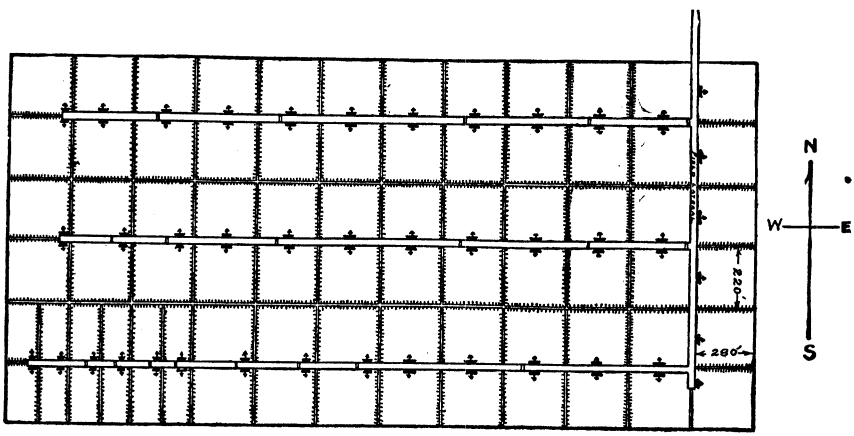

FIG. 5.—Layout of rectangular checks on a farm near Modesto, Calif.

short side on the steep slope. A fall of 3 to 5 inches between adjacent checks is preferable to either more or less. Usually the width of checks can be so adjusted as to permit of this difference in elevation. The length of each rectangle will depend on the slope in that direction as well as the location of the supply ditches. The field should be laid out in such a way that the levees may be built with the least handling of dirt. Rectangular checks possess many advantages over irregular contour checks, but if much of the better quality of surface soil has to be removed in order to build the former, the advantages may be more than outweighed by the damage caused by grading and the extra cost.

Figure 5 shows in outline the rectangular checks, supply ditches, and check boxes on a farm east of Modesto, Calif. The owner plows the land in the early spring to a depth of 6 inches with a four-gang plow. During the summer the checks and ditches are built in a rough way, no effort being made to level the floor of the checks or to smooth the levees and ditch banks. Then it is irrigated heavily, and after the soil is sufficiently dry the floor of each check is leveled

carefully and the levees trimmed and smoothed. For the latter purpose the grader shown in Figure 6 is preferred. One passage of this grader across the top of each levee and once along each side reduces the levee to a base of 14 feet, and a height of 8 inches on the high side and 10 inches on the low side. On the west side of the San Joaquin Valley the land to be seeded to alfalfa is almost invariably formed into contour checks. A common arrangement is that shown in figure 7. Here the supply ditches are intended to be about 600 feet apart, and levees are built midway between. The sides of the checks conform in a measure, but not exactly, to the natural contours, having a difference in elevation of 0.3 to 0.4 foot. In 1908 prices were obtained on the cost of preparing land in contour checks and seeding to alfalfa. The average cost on 2,067 acres of comparatively smooth grain land was $11.46 per acre. Across the river in Modesto and Turlock districts, where rectangular

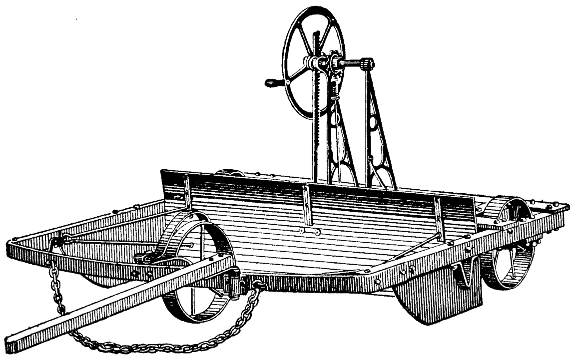

FIG. 6.—Grader.

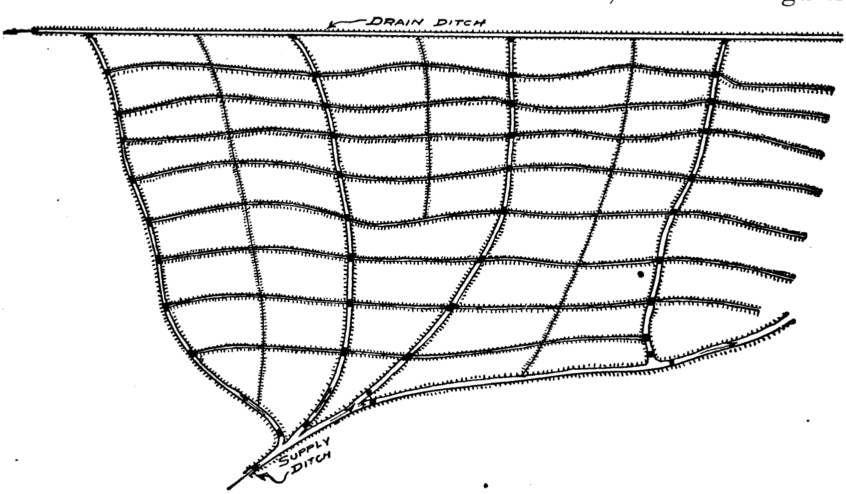

FIG. 7.—Contour checks.

checking is more common and where the natural surface is more uneven, the cost was estimated at $17.50 for contour checks and $19 for rectangular checks. The latter figures included ditching, but excluded the cost of seed and seeding. The cost of preparing land at present (1925) is about 60 per cent higher than it was in 1908.

In the Modesto and Turlock irrigation districts the feed ditches are designed to carry large heads of 10 to 20 cubic feet per second.

These large heads are used by the farmers in turn for short periods of time, depending upon the acreage served. In the smaller checks a head of 5 cubic feet per second will suffice, and if 20 cubic feet per second is available four checks may be irrigated simultaneously. This head flowing on a check containing 1 acre would cover it to a depth of about 5 inches in one hour. A part of the water so applied is always lost by evaporation, but the balance percolates into the soil to furnish moisture to the plants. The skillful irrigator begins with the highest checks and works down for the reason that all waters which escape through the gopher holes or broken levees may be then applied to dry checks. To reverse this rule might result in over-irrigating the lower checks. The average cost of irrigating for the season where proper check boxes are inserted is about 95 cents an acre.

On the west side of the San Joaquin River each of the irregular compartments contains 1 to 3 acres, averaging about 2 acres. Few permanent wooden check boxes are used. The water is checked up by dams of coarse manure, and an opening is made in the levee bank with a shovel to admit the water. The lack of suitable boxes to control the water passing from the feed ditch into each check and the use of smaller heads greatly increase the cost of irrigating over that of the Modesto and Turlock districts. In the latter the cost for the season of 1908 was estimated at 60 cents per acre, while in the former the estimate is 90 cents for each watering.

The chief advantage of the check method is that one man can attend to a larger volume of water and can irrigate 7 to 15 acres in 10 hours, making the cost of applying water less than by any other method except the border method. To counterbalance this important gain, there are several disadvantages which western farmers ought to consider. These are the removal of a considerable quantity of surface soil to form the levees, which frequently decreases the yield on the graded spots; the extra cost of preparing the land; the damage done to farm implements in crossing levees; and the fact that this method is not well adapted to a rotation of crops.

THE FLOODING METHOD.

Flooding from field ditches or laterals is still the most common method of applying water to the arid lands of western America. In the States of Colorado, Montana, Nevada, Wyoming, Utah, and to a large extent in Idaho, alfalfa, clover, native meadows, and grain are irrigated in this way. This manner of wetting dry soil originated, it is believed, in the mountain States, and the last half century has seen a gradual evolution of this plan, so that now it has not only become firmly established, but is regarded as the best suited to the conditions under which it is practiced. It can be profitably used on slopes that are too steep for other methods. Fields having a firm soil and a fall of 25 feet to 100 feet per mile have been flooded successfully. From this extreme the slope may diminish to less than 0.1 foot in 100 feet. Its cheapness is another feature which recommends it to the farmer of limited means. Ordinary raw land can be prepared for flooding at an expense of $5 to $12 per acre. Again, it is adapted to the use of small water supplies. In the mountain States the irrigation systems have been planned and built to deliver

water in comparatively small streams for use in flooding or in furrows, and water users should be certain that the larger volumes required for checks and borders can be secured before going to the expense of preparing their fields for either of those systems.

In grading the land for this particular method it is not customary to make many changes in the natural surface. Only the smaller knolls are removed and deposited in the low places. An effort is made always, however, to make the farm laterals fit into the natural slope and configuration of the tract to be watered so as to bring the water to the high places. On steep slopes the laterals may be less than 50 feet apart; on flatter slopes they may be 200 feet or more apart. Whatever the spacing it is always desirable to have the slope between them as nearly uniform as possible. When the land in its natural state is uneven, the grading can be done best by a grader of the kind shown in Figure 6, page 7, or a scraper of the kind shown in Figure 8. When these are used, it is often advan-

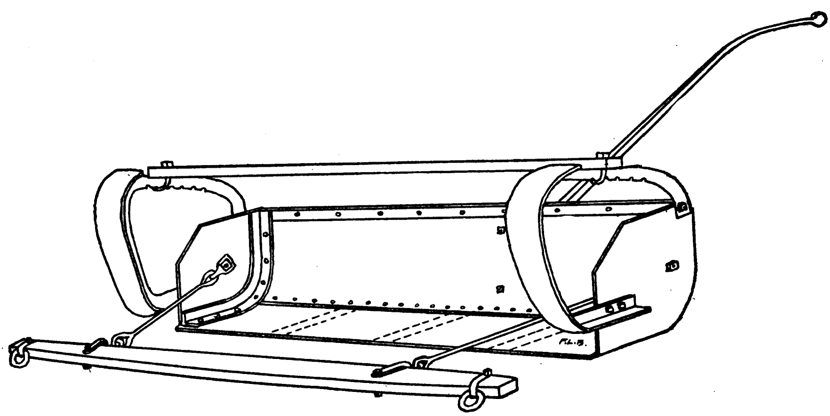

FIG. 8.—Fresno scraper.

tageous to make use of some such implement as the leveler shown in Figure 9 for the final smoothing and grading. If the field in its natural state is comparatively smooth and level a homemade drag or leveler, as shown in Figure 10, serves the purpose fairly well.

The distribution of the ditches on the field varies too widely to admit of presenting a standard plan, but Figure 11 shows an arrangement of field laterals common to the mountain States. A supply ditch, AB, is built on one side and laterals, CD and EF, branch out from it on a grade of 0.5 to 0.75 inch to the rod. These laterals are spaced 75 to 100 feet apart and are made with double moldboard plows or listers, either walking or sulky. Figures 12 and 13 illustrate other common arrangements in use in northern Colorado.

In the vicinity of Fort Collins, Colo., the main lateral is built to the highest corner of the field to be irrigated and the smaller laterals extend out from it, spaced 75 to 225 feet apart, the spacing depending on the slope of the ground and the coarseness of the soil. The size of the laterals is governed by the head which may be had, but on steep slopes and on soil that erodes readily, small heads are best. Around Berthoud, Colo., the land is naturally of uniform, even slope,

and little grading has been necessary. Heavy timber or iron drags are used to smooth the surface after plowing so that the water will spread evenly. These are built in various ways and out of whatever material happens to be available on the farm. Worn-out steel rails, such as have been removed from a railway, are often used, two rails

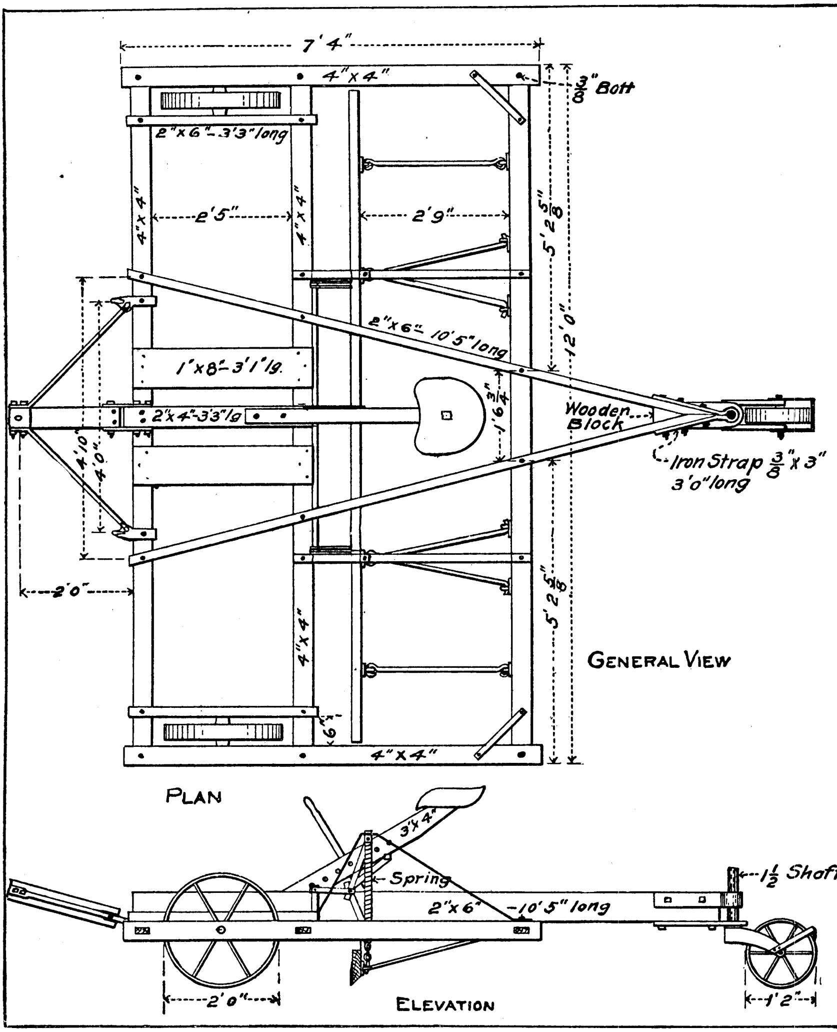

FIG. 9.—Leveler used in Gallatin Valley, Mont.

being fastened together about 30 inches apart. A team is hitched to each end and the driver rides on the drag. Once over a field with a drag of this kind usually is sufficient to make the surface uniform and smooth. The proper location for field laterals usually is evident to the irrigators without the use of surveying instruments, though in fields where the fall is slight it often is necessary to have a topographical survey made and the laterals located by an engineer. Field

laterals always are so located that they cover the highest parts of the field and their distance apart in alfalfa varies from 10 to 20 rods.

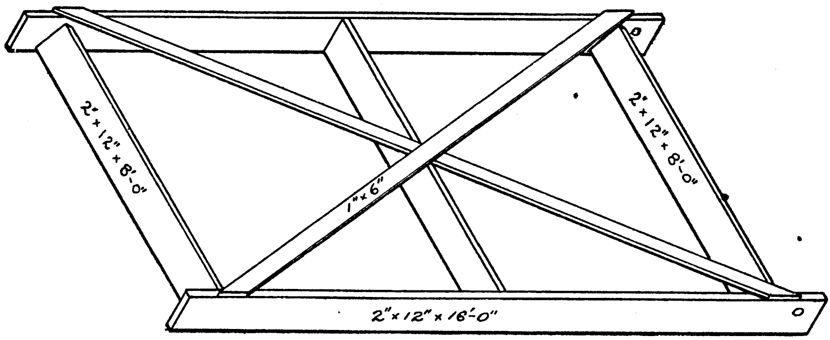

FIG. 10.—Homemade drag or leveler.

The head required for flooding from field laterals in northern Colorado varies from 2 to 3 cubic feet per second and is divided between two or three laterals. Canvas or coarse manure dams are used to check the water in the laterals and to force it out over the banks and down the slopes of the field. In less than three hours the upper foot of soil usually is thoroughly moistened. To apply one watering in this way costs from 35 to 60 cents an acre.

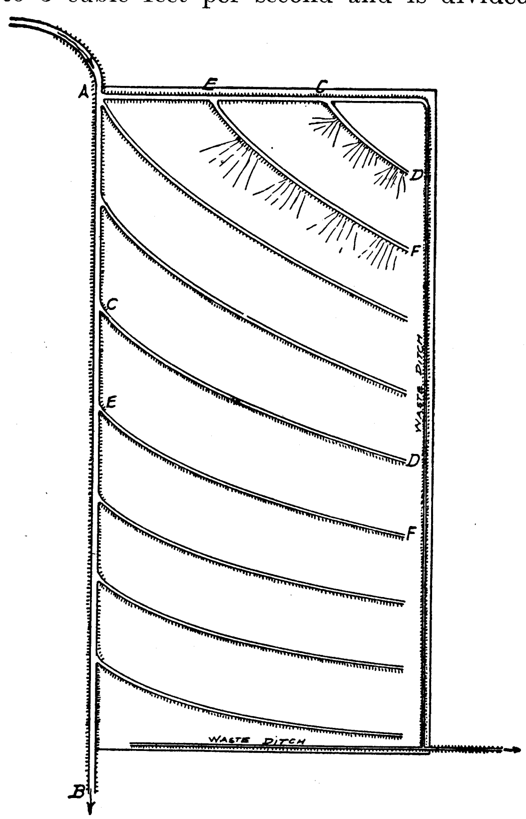

FIG. 11.—Field prepared for flooding in Montana.

In flooding clover and alfalfa fields in Montana the field ditches usually run across the field on a grade of 0.5 to 0.75 inch to the rod. (See fig. 11.) The spacing between ditches varies with the slopes, the smoothness of the surface, and the volume of water, but 80 feet is about an average. The head used is seldom less than 1.5 or more than 4 cubic feet per second, the larger heads being divided between two or three ditches. In irrigating, a canvas dam is first inserted in each ditch or set of ditches, 75 to 100 feet below the head. The water is then turned into each channel and flows as far as the canvas

dam, by which it is checked and as a consequence rises and flows over the low places of the lower bank or through openings made with the shovel. When these small tracts have been watered, the canvas dam is raised, dragged down the lateral 75 to 100 feet, and again inserted in the channel to serve the next tract. In some sections it is customary to use two dams, one being placed below the other before the first is removed. Manure or earth dams sometimes take the place of the movable canvas dams. Some time before a field is to be irrigated and after the ditching is done, coarse manure is placed in small heaps within each ditch channel at suitable intervals and each heap is covered with earth on its upper face to a depth of 1 to 2 inches. When this check has served its purpose it is broken and the water flows down until stopped by the next check. In some instances permanent wooden check boxes are inserted in each lateral, while in others the canvas dam is used. The thorough irrigation of 4 acres is considered a good 12 hours' work for one man. By the use of 100

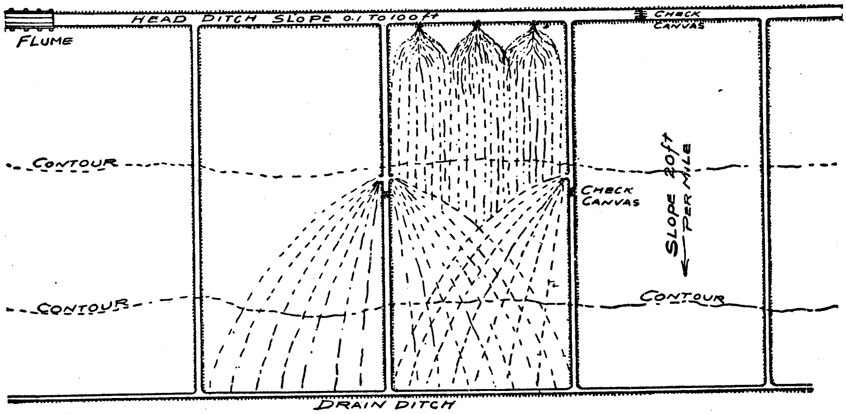

FIG. 12.—Flooding from head ditches in northern Colorado.

miner's inches, two men can irrigate 7 to 10 acres in 24 hours at a cost of 85 cents to $1.25 per acre.

In the Salt Lake Basin the heads of water used by the irrigators of alfalfa vary considerably with the flow of the streams. Irrigating heads of 4 to 6 cubic feet per second are common, while later in the season when the streams are low they are reduced to 1 to 3 cubic feet per second. A field usually is divided into strips 200 to 500 feet wide by laterals extending across it (fig. 12). A permanent wooden check box or a canvas dam is inserted in the main supply ditch below each cross ditch, causing the water to flow into the cross ditch. From there it is spread over the surface through small openings in the ditch bank and any excess water is caught up by the next lower ditch. In this way each ditch serves a double purpose, acting as a drainage channel for the land above it and as a supply channel for the land below it.

In summarizing the advantages of the flooding method, it may be said that in first cost it is one of the cheapest, it is adapted to the delivery of small volumes of water (50 to 100 miner's inches) in continuous streams, it is particularly well adapted to forage and cereal

crops of all kinds, the top soil is not removed from the high places to fill up the low places, and firm soil, although it be on steep and irregular hillsides, can be watered successfully.

The chief disadvantages consist in the fatiguing labor required to handle the water, the small area which one man can irrigate in a day, the difficulty in applying water after dark, and the unequal distribution of water on the field unless more than the average care is exercised. The latter objection is important, since uneven distribution decreases crop returns and wastes water.

THE FURROW METHOD.

Alfalfa, native meadows, and grain are irrigated most commonly by one of the methods previously described rather than by the furrow

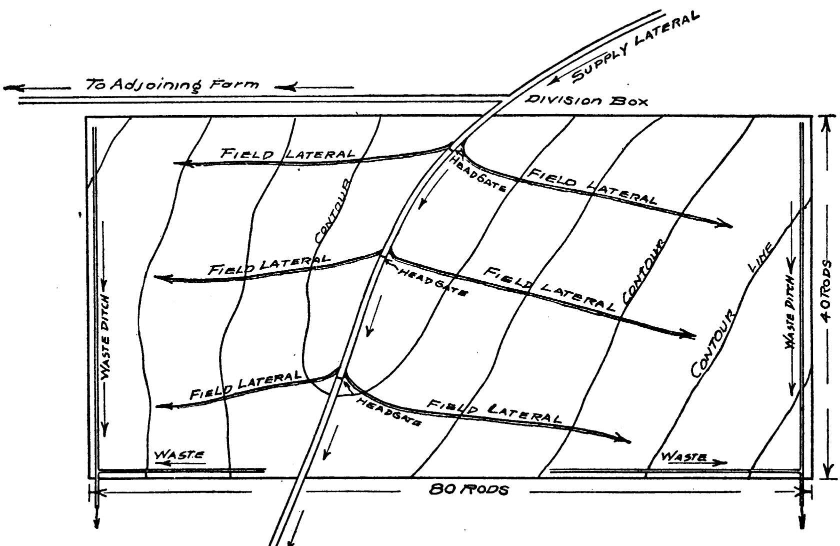

FIG. 13.—A 20-acre alfalfa field near Berthoud, Colo., showing supply lateral, field laterals, contours, and waste ditches.

method, which is the usual method of irrigating orchards, gardens, root crops, and vegetables. The irrigating of alfalfa from furrows is at present confined to the Yakima Valley, Wash., portions of the Snake River Valley and near-by areas in southern Idaho, and comparatively small areas in other States. In the localities named the soil is a fine clay loam, which runs together, puddles when wet, and bakes and cracks when dry. Flooding the surface by any of the customary methods tends to puddle the top layer of soil, which becomes quite hard when the moisture is evaporated. The puddling and baking processes injure alfalfa, and it was with the object of keeping as much as possible of the surface dry that furrows were introduced. When a small stream is permitted to run in the bottom of a furrow for several hours, the soil beneath and for some distance on each side becomes wet, while the

surface may remain nearly dry. This is shown in Figure 14, which shows the area wetted from a furrow 5 inches deep in seven hours as determined in one of the orange orchards of southern California.

The alfalfa grown in the Yakima Valley in Washington is practically all irrigated by means of furrows. The grading is usually done by buck scrapers (fig. 15), while a long, rectangular drag similar to the one shown in Figure 10 (p. 11) removes most of the surface inequalities that remain after the surface has been leveled roughly by the scraper. The float is made of two 2 by 6 inch timbers about 20 feet long, held in position by crosspieces of the same size and 6 feet long.

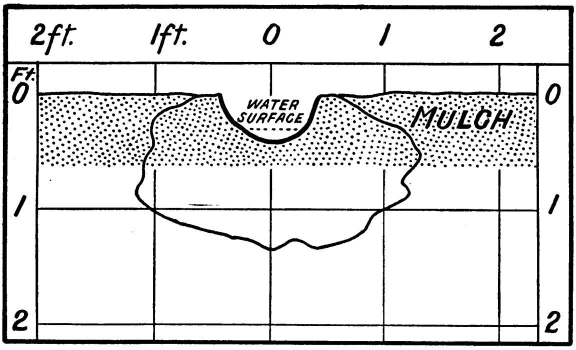

FIG. 14.—Outlines of percolation from furrow 5 inches deep, in seven hours.

The common practice is to run the furrows across the entire width or length of a field, and in consequence their length varies from 20 rods or less in small fields to 80 rods in large fields. As a rule, the furrows are too long. Farmers object to cutting up a field by head ditches, but in a climate like that of the Yakima Valley in midsummer by far the most essential element in plant production is water, and all other considerations should give place to it. It has been shown[1] that water is rarely distributed evenly in furrow irrigation and that much is lost by deep percolation. To increase the length of a furrow beyond 660 feet, or one-eighth mile, not only increases the loss but renders a uniform distribution more difficult to secure. Except in rare cases, this distance should be regarded as the limit for the length of furrows. In light, sandy soils, having a porous gravel stratum beneath, the length may well be reduced to 250 feet.

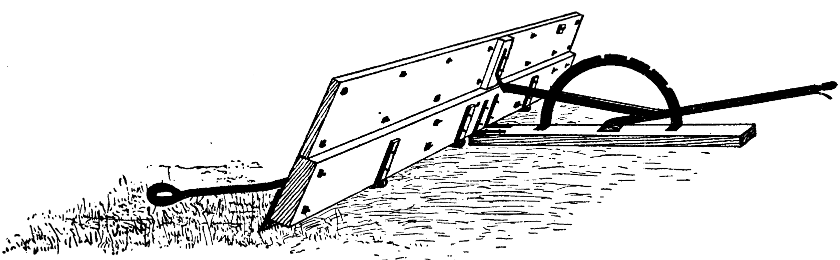

FIG. 15.—Buck scraper.

Figure 16 shows the manner of dividing an alfalfa field for furrow irrigation at Kennewick, Wash. Wooden head flumes, either 8 by 8 inches or 6 by 6 inches, are placed along the upper boundary

[1] U. S. Dept. Agr., Office Expt. Stas. Bul. 203.

of each strip and the direction of the flow in both flumes and furrows is indicated by arrows. Auger holes are bored through one side of the flume flush with the bottom at points where water is to be delivered to the heads of furrows. A short piece of lath revolving on a nail controls the flow from each opening. On steep grades a cleat on the bottom of the inside of the flume nailed on crosswise just below each opening will dam back the water and increase the discharge.

When flumes are considered too costly the water is distributed among the furrows through wooden spouts set in the bank of an ordinary earthen ditch. Figure 17, sketched from a model, gives a general idea of this method of irrigation, while Figure 18 shows its

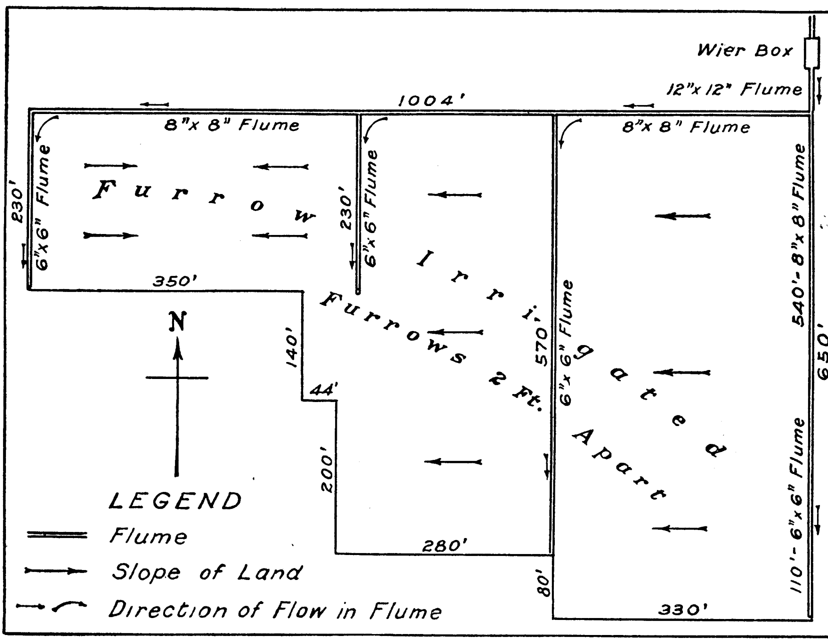

FIG. 16.—Showing tract prepared for furrow irrigation.

practical application to field conditions. These head ditches when in operation are divided into a series of level sections by means of drop boxes which hold the surface of the water at the desired elevation. The spacing of these drop boxes depends on the grade of the head ditch and their cost averages about $4 each. Spouts are made usually by nailing together four laths. There is a special lath on the market somewhat heavier than the ordinary one used for plastering buildings, being 0.5 inch thick, 2 inches wide, and 3 feet long. Four of these when nailed together cost about 7 cents and each spout in place costs about 13 cents. Assuming that they are spaced 4 feet apart the spouts for a square tract of 10 acres would cost $21.50 or slightly more than $2 per acre. The cost of an ordinary head ditch, with four drops or check boxes, would be about $25 for the same tract, or $4.50 per acre for both, exclusive of grading, smooth-

ing, and leveling. Tin tubes, 0.5 inch in diameter, one to each furrow, have sometimes been used instead of the wooden tubes. When set 0.5 inch below the water surface each tube discharges about 0.1 miner's inch, which is about right for a slope of 3 per cent. The

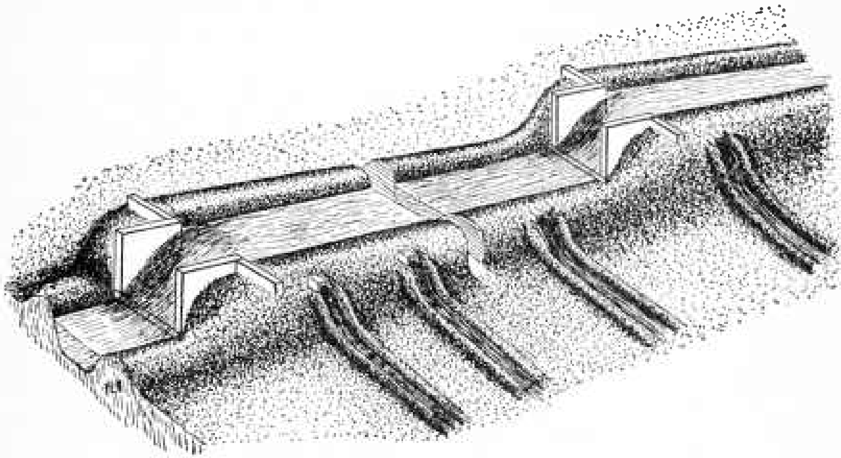

FIG. 17.—Manner of placing tubes in ditch bank for furrow irrigation.

length of the tin tubes is governed by the size of the ditch bank. The tubes are set while the water is in the ditch and are kept at the same level between check boxes. The cost of tin tubes 2 feet long is

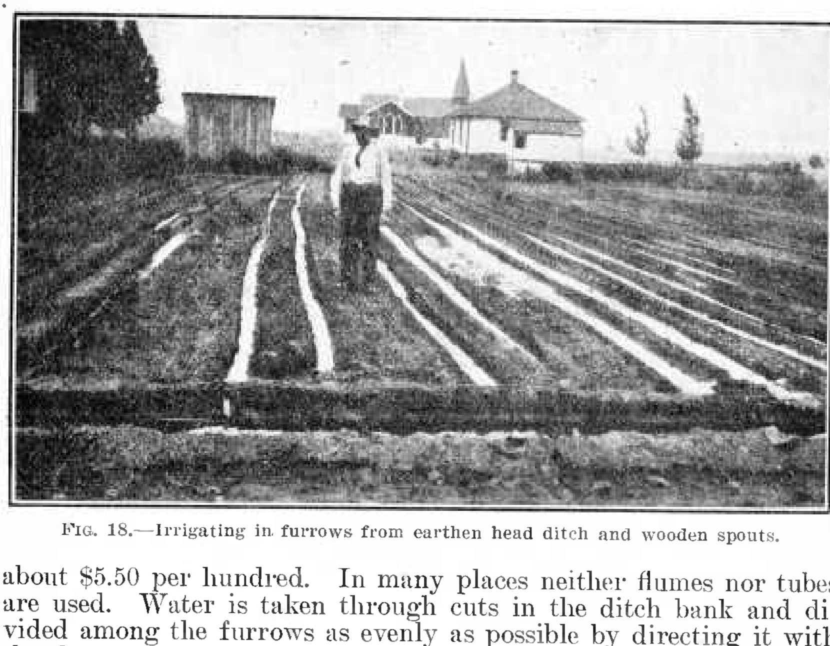

FIG. 18.—Irrigating in furrows from earthen head ditch and wooden spouts.

about $5.50 per hundred. In many places neither flumes nor tubes are used. Water is taken through cuts in the ditch bank and divided among the furrows as evenly as possible by directing it with the shovel. This practice reduces the cost of preparing the land for irrigation, but it increases the cost of applying water, and does not

secure an even distribution among the furrows and it is not recommended.

Furrows in alfalfa fields are most commonly made by the use of a furrowing sled (fig. 19). Sleds with three runners are sometimes used, as shown in Figure 20, reducing the time required for furrowing, but not producing quite so satisfactory furrows, since an obstruction under one of the outside runners will lift all but the other outside runner out of the ground and leave obstructions in the furrows, which, if not removed, will cause the flooding of the surface. The marker attached to the sled shown in Figure 20 is a good device and should be used in two-runner sleds, since it indicates the place for the next furrow.

For the irrigation of most of the crops grown in the vicinity of Twin Falls, Idaho, the feed ditches are laid out across the field as nearly parallel as possible on a grade of 2 to 6 inches to 100 feet and 300 to 500 feet apart. Furrows are made in the direction of the greatest slope and approximately at right angles to the feed ditches. Starting at the upper end, a wooden check is inserted in the ditch at the end of each fall of 12 inches. Thus, if the ditch has a fall of 4 inches to 100 feet the checks are placed 300 feet apart. Each check box is provided with a removable flashboard, which, when in place, backs the water to the next check above and at the same time permits the surplus water to flow over its top to supply the checks below (fig. 21). Lath tubes 16 to 24 inches long are inserted in the lower ditch bank about 3 inches below the water level formed by the flashboards when in place. These tubes are put in while the check is full of water in order that all of each set may be on the same level and that water may be had for puddling. The flow from each tube may be divided among several furrows. Ordinarily a 40-acre farm will require about 30 check boxes and 1,800 tubes. Nearly one-half the tubes ought to be 24 inches long to insert near the check boxes where the bank is heaviest, while the remainder may be 16 inches long. The check box shown in the sketch (fig. 21) calls for 17 feet b. m. of lumber, but a serviceable box can be made out of old packing boxes.

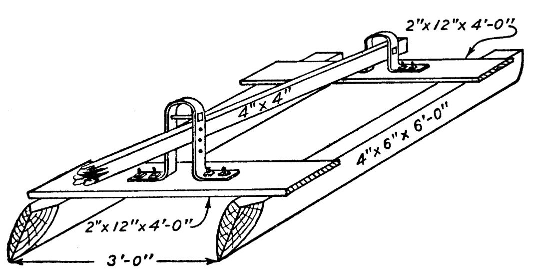

FIG. 19.—Furrower used on experiment farm, Riverton, Wyo.

Some of the advantages of this method over ordinary furrow irrigation are: A constant head over the inlets of each set of tubes while the surplus passes down the field ditch; the opportunity to use one or all or any combination of checks at the same time, as it is possible to regulate the head and consequently the discharge by raising or lowering the flashboard; and the automatic character of the water distribution while irrigating.

No fixed rule can be given as to the proper spacing of the furrows or the time water should run in each. In heavy retentive

soils the furrows may be 2 to 2.5 inches deep and only 16 inches apart, while in more open soils the furrows may be 48 inches apart.

The amount of water which should flow in each furrow depends on the character of the soil and the slope. It is a common practice in the Yakima Valley to space the furrows 18 to 24 inches apart when the seeding is done, but as the plants grow their roots soon penetrate several feet into the soil and alternate furrows are then abandoned. If the tract contains 10, 20, or 30 acres the furrows run all the way across, if the slope will allow it. Water frequently is run a quarter of a mile in the small furrows. In furrows 660 to 1,320 feet long in sandy loam, the water has to be kept running continuously for about two days, and consequently there is usually much waste due to deep percolation. In distributing water in furrows it is a good plan to follow the practice of the irrigators of the orange belt in southern California, who turn into each furrow, until the furrows are wet, three or four times as much water as will be permitted to remain, and then reduce the flow.

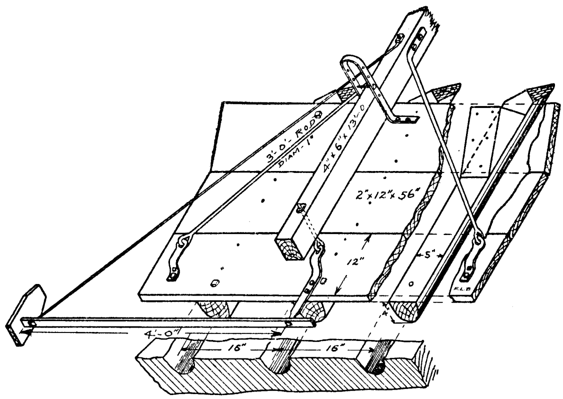

FIG. 20.—A three-runner sled with marker.

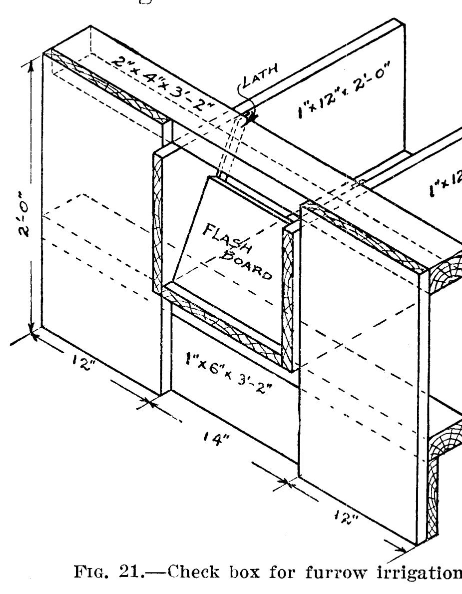

FIG. 21.—Check box for furrow irrigation.

THE USE OF PORTABLE PIPE.

In southern California, where large areas of alfalfa are irrigated with water pumped from wells at considerable expense, great care is exercised to prevent waste of water. Concrete pipe lines are laid to convey water from the pumping plants to the fields. Usually these are 10 inches in diameter, though 12-inch pipe is used in some instances. The head lines, along the high sides of fields, are provided with stands about 100 feet apart. The type of stand used most commonly is illustrated in Figure 22. A section of 12-inch

concrete pipe is cemented to the supply pipe. This is provided with a valve which can be removed to permit the insertion of an 8-inch galvanized iron elbow to which the distributing pipe can be attached. As shown in Figure 22 the top of the stand and valve is several inches below the general ground surface so that there will be no obstruction to the mowing machines. The 10-inch valve, which is used with a 12-inch standpipe, costs about $2.75.

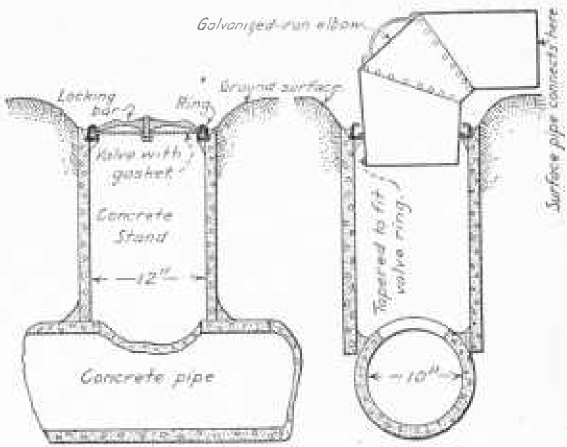

FIG. 22.—Stand, valve, and elbow for irrigating with portable surface pipe.

In many instances water is forced through the pipe line by the pump, and usually an open standpipe is placed in the line near the pump to relieve the pressure on the pipe line if all valves are closed.

The cost of a head line for 40 acres, with 1,300 feet of 10-inch pipe laid at 22 cents per foot, 12 stands at $1.75 each, and one basin at $5 is $312. Iron stands which are more convenient to open and close are made, but because of their greater cost they are not yet in general

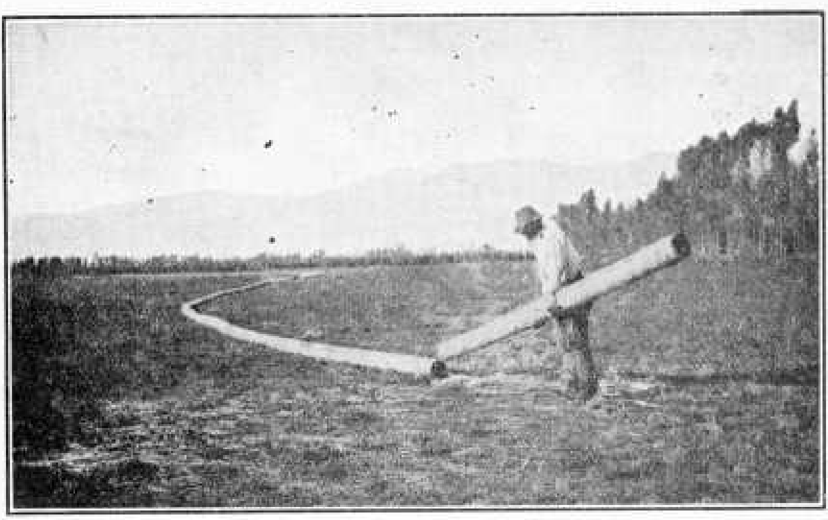

FIG. 23.—Use of portable pipe in irrigating alfalfa.

use. Portable slip-joint pipe is attached to the stands in turn, and the water is conveyed to all parts of the field through this pipe (fig. 23). This pipe is made of galvanized iron, usually 24 gauge.

It is 8 inches in diameter and is made up in sections of several lengths, but the shorter lengths of 10 feet have been found to be most durable, and are preferred. Some of the latest pipe is in 10-foot sections, each made from a single sheet of metal, as shown in Figure 24. Aside from the circumferential seam at one end where the taper begins, this section has only a longitudinal seam, which is soldered

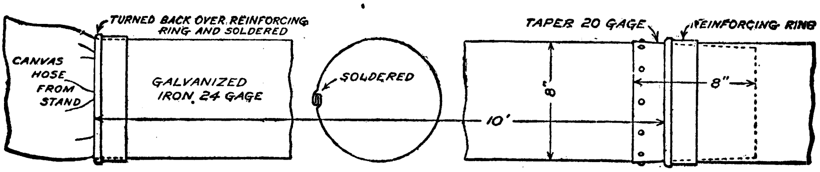

FIG. 24.—Surface pipe for irrigating alfalfa.

but not riveted. The taper is 8 inches long and is of heavier iron (about 22 gauge) for inserting in the end of another section. The pipe costs about 35 cents per linear foot, and 1,300 feet, which is sufficient to irrigate a square 40-acre tract from one head line, will cost $455. The expense is warranted by the productiveness of the

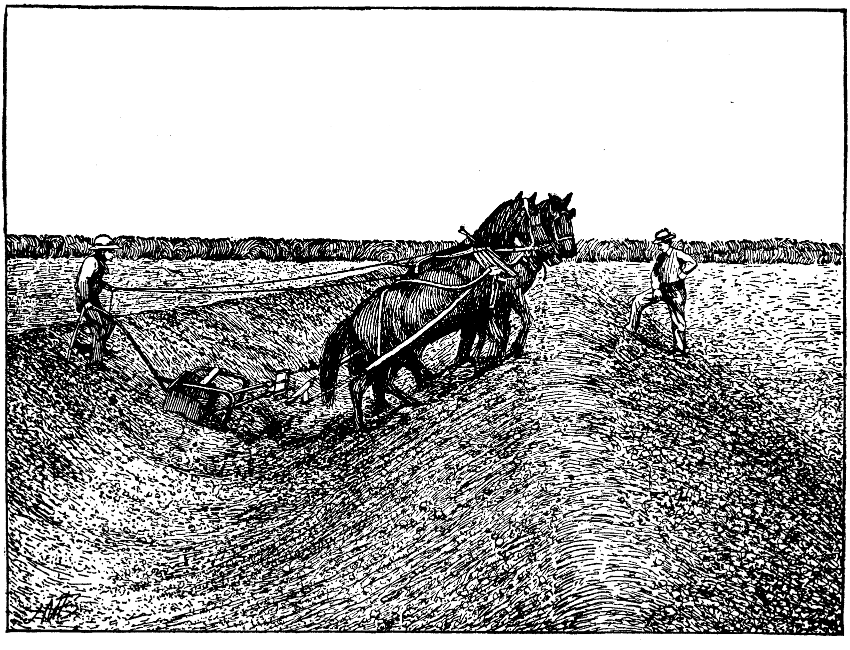

FIG. 25.—Building a supply ditch.

land and the permanency of the crops. Some pipe is not furnished with the reenforcing ring and the taper is formed by merely crimping the end, but this is a less durable kind. The cost is double the cost of hose, but it lasts for 10 or 15 years or even longer with proper handling. The principal source of damage is in the loading and unloading of the sections when hauling to or from the field.

With a head of 60 miner's inches one man can irrigate 2½ acres per day of 10 hours. To irrigate a field the water is used from one stand for a strip equal in width to the distance between stands and with length from the head to the foot of the field. Since without reservoirs there must be an outlet for the water whenever the pump is in operation, it is best to have one stand open temporarily when the surface pipe is being connected to another. The best way to irrigate with surface pipe is to begin applying water at the upper end of the strip, and proceed toward the lower end by adding sections of pipe.

When care is used there need be no waste and no draining of surface water to prevent scalding. If too much water is being applied, it will flow toward the lower side of the field, and as the work approaches the foot it is easy for the irrigator to make proper allowance for the surplus. When one strip has been watered the irrigator begins at the upper end by carrying the pipe across to the new location section by section. The second stand is opened and the new connection made before the first stand is closed. The leakage at the joints of pipes is slight and the loss is not of consequence since it occurs on the land being watered.

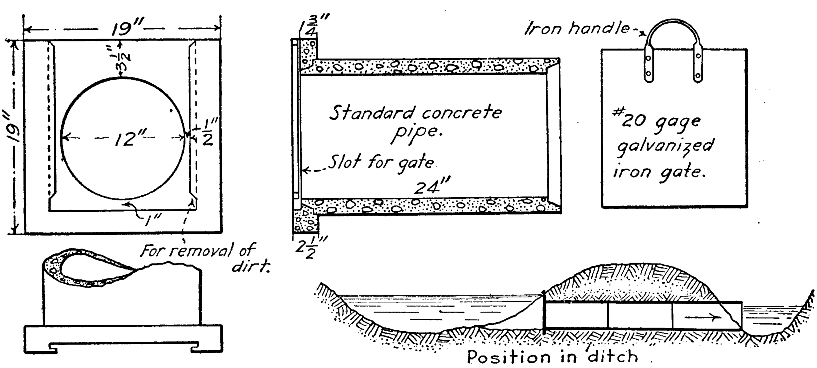

FIG. 26.—Ditch and border gate used in Imperial Valley.

The advantages of irrigation with pipe may be summarized briefly as follows:

(1) Losses which otherwise would occur by seepage in the conveyance of water over a field are prevented. Further loss in application due to gopher and squirrel holes also is eliminated largely.

(2) A small stream may be handled effectively over a large area, and the irrigator may apply the stream at any point of the field he desires.

(3) No field laterals are required, which is a direct saving in the crop-producing area of a field, as well as in the time required to construct and repair these laterals.

(4) With no laterals and the surface of the land free from obstructions, crops can be harvested with greater ease and with less wear and tear on farming machinery.

(5) With pipe, land can be irrigated with little or no preparation, although it is better to level land to some extent if it needs it.

(6) Introduction of noxious weeds into a field is less likely to occur.

The disadvantages are:

(1) Initial cost is high, especially where underground pipes form part of the system.

(2) Pipe requires careful handling to prevent damage.

(3) It is necessary to have pressure head on pipe in order that a fair-sized stream may be carried in conduits of medium sectional area.

Field irrigation with pipes undoubtedly is impracticable in many sections of the West on account of high cost. Numerous other sections, like southern California, possessing a scanty water supply, could well adopt the practice and thus extend the area watered with their small supply. Light portable pipe also is being used to distribute irrigation water in the Atlantic Coast States.

FARM DITCHES.

The capacity and, to some extent, the location of farm ditches depend chiefly on the method of applying water. In the border method the supply ditch usually is large and so located as to convey a sufficient volume of water to the head of each land. In Imperial Valley in California these head ditches, as they are called, have a bottom width of 3 to 4 feet and a surface width of 6 to 10 feet. In building a

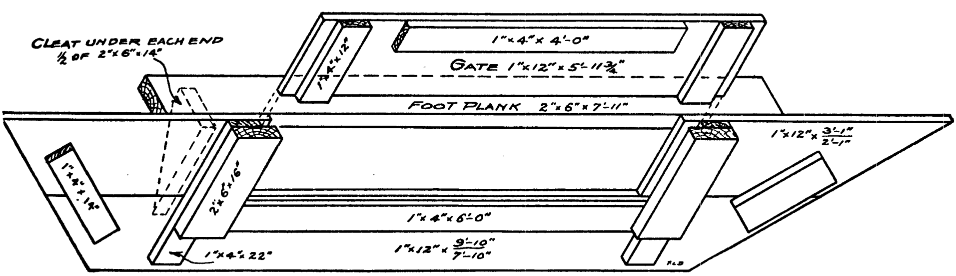

FIG. 27.—Border gate used near Sunset City, Calif.

ditch of this size a strip 3 or 4 feet wide on the center line of the ditch is plowed 6 inches deep. Then parallel strips, 6 feet wide, are plowed 8 feet distant from it. Scraper teams then cross and recross these, taking dirt from the plowed strips and dumping it on the unplowed spaces to form the banks (fig. 25). The banks when completed are about 2 feet above the natural surface of the ground, and the bottom of the ditch is 6 to 10 inches below it. When it is deemed best not to create a depression at the outer toe of each embankment, the borrowed dirt is taken from the high parts of the adjacent land.

The water required for each land is withdrawn from the head ditch through a border gate. These usually are made of concrete, Figure 26 showing the type of border gate used, which is made in sizes of 4 to 24 inches. Usually 24-inch gates are used for main supply ditches, and 12-inch gates are used on the field head ditches to let water into the checks on borders. The pipe is made of a 1 to 4 mixture, and the head piece is made of a 1 to 2 mixture and the form is removed after two days. The pipe is cured before the head is molded on it. One or two extra joints of pipe are used with each gate. The capacity of a 12-inch gate is about 3

second-feet, and the cost is from $2.50 to $3 each. It costs about 40 cents to set each gate.

A cheaper border gate is shown in Figure 27, which represents the kind used on an alfalfa tract at Sunset City, Calif. In some localities concrete is being substituted for wood and Figure 28 shows a border

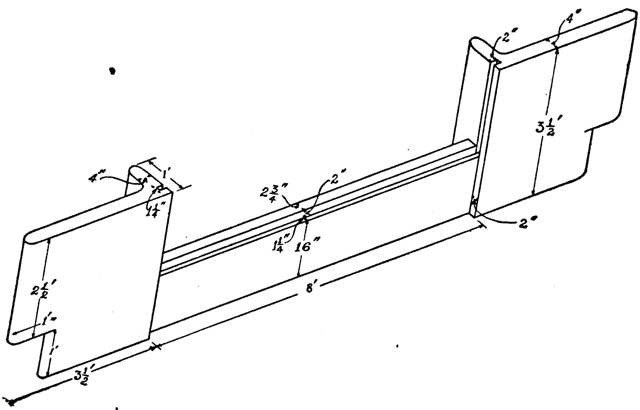

FIG. 28.—Concrete gate used in Yolo County, Calif.

gate of this material, quite generally used for the irrigation of alfalfa in Yolo County, Calif.

In the check method of irrigation the volumes used do not differ materially from those required to flood the lands in the border

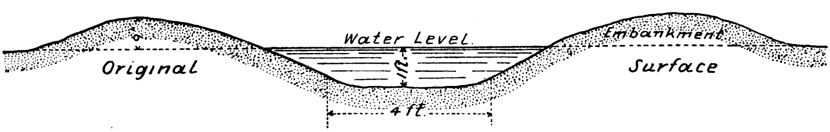

FIG. 29.—Supply ditch with bottom width of 4 feet.

method, and the feed ditch for the checks corresponds in size and capacity to that of the head ditch for borders. Cross sections of common forms of supply ditches are shown in Figures 29 and 30. The carrying capacities of these ditches under different grades are given in the accompanying table:

Mean velocity and discharge of ditches with different grades.

SUPPLY DITCH, FIGURE 29.

Grade.			Mean velocity in feet per second.	Discharge.	
Inches per rod.	Feet per 100 feet.	Feet per mile.		Cubic feet per second.	Miner's inches under 6-inch pressure head.
1/16	0.03	1.58	0.84	4.20	168
1/8	.06	3.33	1.08	5.40	216
1/4	.13	6.67	1.54	7.70	308
3/8	.19	10.00	1.89	9.45	378
1/2	.25	13.33	2.20	11.00	440
5/8	.31	16.67	2.45	12.25	490
3/4	.38	20.00	2.69	13.45	538

Mean velocity and discharge of ditches with different grades—Continued.

SUPPLY DITCH, FIGURE 30.

Grade.			Mean velocity in feet per second.	Discharge.	
Inches per rod.	Feet per 100 feet.	Feet per mile.		Cubic feet per second.	Miner's inches under 6-inch pressure head.
1/16	0.03	1.67	1.03	11.60	464
1/8	.06	3.33	1.48	16.70	668
3/16	.09	5.00	1.82	20.50	820
1/4	.13	6.67	2.11	23.75	950
5/16	.16	8.33	2.35	26.45	1,058
3/8	.19	10.00	2.58	29.10	1,164
7/16	.22	11.67	2.80	31.58	1,263

In flooding land from field laterals two kinds of channels are needed. The larger ones convey the water to the highest corners of the fields and along one or two borders of each field; the smaller distribute the water over the field. In this method of applying water smaller streams are used than in either the check or border method.

FIG. 30.—Supply ditch with bottom width of 6 feet.

Except on large farms the stream seldom exceeds 3 cubic feet per second, and usually is between 2 and 3 cubic feet. On ordinary grades only a small channel is needed for this volume. Such channels are made by plowing first a strip as wide as the surface of the ditch is to be when full and removing the loose dirt by one of several

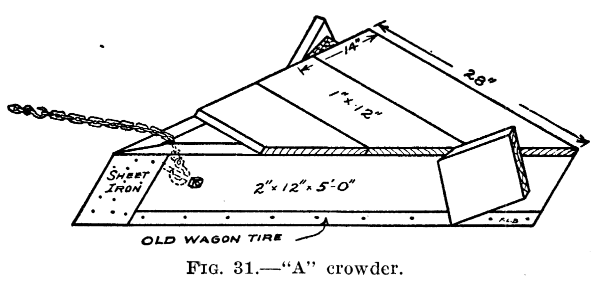

FIG. 31.—"A" crowder.

designs of A crowders, two of which are shown in Figures 31 and 32. One of the best implements for making field laterals is a 14 or 16 inch lister plow on a sulky frame. Figures 33 and 34 show cross sections of lateral ditches made in this way, while Figure 35 represents a common type of supply ditch. The effect which grade has upon such channel is shown in the accompanying table, giving discharges of these ditches, with various grades.

Mean velocity and discharge of ditches with different grades.

Grade.			Mean velocity in feet per second.	Discharge.	
Inches per rod.	Feet per 100 feet.	Feet per mile.		Cubic feet per second.	Miner's inches under 6-inch pressure head.
LATERAL DITCH, FIGURE 33.					
½	0.25	13.33	1.01	0.76	30
¾	.38	20.00	1.23	.92	37
1	.51	26.67	1.42	1.06	42
1¼	.63	33.33	1.59	1.19	48
1½	.76	40.00	1.75	1.31	52
2	1.01	53.33	2.04	1.52	61
2½	1.26	66.67	2.28	1.70	68
3	1.51	80.00	2.50	1.87	75
3½	1.77	93.33	2.70	2.02	81
LATERAL DITCH, FIGURE 34.					
¼	0.13	6.67	0.80	0.89	33
½	.25	13.33	1.17	1.22	49
¾	.38	20.00	1.41	1.47	59
1	.51	26.67	1.67	1.74	70
1¼	.63	33.33	1.87	1.95	78
1½	.76	40.00	2.05	2.13	85
1¾	.88	46.67	2.121	2.30	92
2	1.01	53.33	2.37	2.47	99
2½	1.26	66.67	2.66	2.77	111
SUPPLY DITCH, FIGURE 35.					
⅛	0.06	3.33	0.79	2.08	83
¼	.13	6.67	1.13	2.97	119
½	.25	13.33	1.60	4.20	168
¾	.38	20.00	1.97	5.20	208
1	.51	26.67	2.28	6.00	240
1¼	.63	33.33	2.57	6.76	270

SUBIRRIGATION OF ALFALFA FIELDS.

As a general thing, alfalfa is irrigated from the surface downward by one of the methods previously described. There is, however, a small percentage of alfalfa lands, probably not more than 5 per cent of the total, which is irrigated from below. Frequently the seepage water from porous, earthen ditches and the waste water from irrigated areas pass through the subsoil of lower fields sufficiently near the surface to subirrigate them. In other places these seepage waters collect at the lower levels and raise the ground water near enough the surface to supply the plants with the needed moisture. It is questionable if alfalfa growers should place much dependence on this mode of supplying moisture to the plant. What is gained in not having to irrigate usually is more than lost in damage done to both soil and crop by the rise of the ground water. Wherever alkali is prevalent the rise of the ground water near the surface is almost certain to be followed by an accumulation of alkali on the surface. Again, the fact that alfalfa fields subirrigate is usually nature's way of giving warning that the ground water is rising dangerously near the surface, and observations should be made to determine if the level is above the danger limit. One of the best ways of making

such determinations is by means of bored test wells. These are made by boring holes from 2 to 4 inches in diameter in different parts of the field and noting at regular intervals the elevation of the ground water in each. Where the subsoil is a clay or a clay loam no lining will be necessary other than a joint of drain tile or a short wooden tube. Where the subsoil is loose it may be necessary to line the wells with thin galvanized iron or with a wooden box. The wells may be connected by a line of levels, the elevations being taken on the tops of stakes driven beside the wells. These well records, if taken at weekly or even monthly intervals for several years, will show at a glance not only the position of the ground water, but also its rise and fall throughout the seasons. Whenever it is found that the water table stands for any considerable time at less than 4 feet from the surface

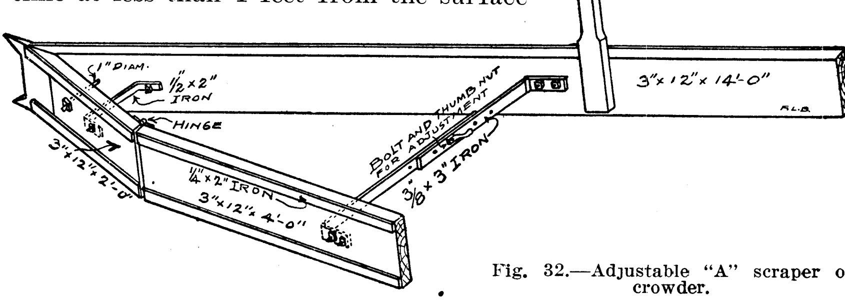

Fig. 32.—Adjustable "A" scraper or crowder.

there is cause for alarm and measures should be taken to prevent such an accumulation of seepage waters or to remove the surplus by drainage.

Alfalfa is subirrigated also from the beds of streams. On bottoms the danger is not so great, because there less alkali is present and the height of the ground water is governed by the condition of the stream. It happens often that when the water table is at its highest point the alfalfa plants are dormant or nearly so, and as

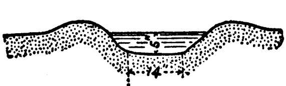

Fig. 33.—Lateral ditch with bottom width of 14 inches.

Fig. 34.—Lateral ditch with bottom width of 16 inches.

a result are not injured so readily. Two cases of successful subirrigation from stream channels are here cited by way of illustration.

On a farm located on the second bottoms about 5 miles northeast of Boulder, Colo., the water table is 10 to 12 feet below the surface. An average yield of alfalfa of 4 tons per acre was obtained for nine consecutive seasons from this farm without any perceptible deterioration. The crop was irrigated the first year, but after that evidently the roots had reached water and continued to draw their supply from that source.

On the Arkansas River south of Cimarron, Kans., is an alfalfa field of over 50 acres which is subirrigated. The water table is found at a depth of 6 to 8 feet, and the yield usually is 1 ton at each cutting.

It is cut three to five times each season, and in some years one crop of seed and two crops of hay are raised.

Throughout the arid region there are a few localities where subirrigation is generally practiced. Perhaps the most notable of these is to be found in the vicinity of the towns of St. Anthony and Sugar City, in the upper Snake River Valley in Idaho. This subirrigated district comprises an area of about 60,000 acres. A characteristic of the subsoil of this large area is that it is composed of sand and gravel, sometimes mixed with cobble rock to the lava bed rock, which is found at depths varying from a few feet to 90 feet. The surface soil around St. Anthony is a dark-colored gravelly loam 2 to 4 feet deep. On the Elgin Bench it is a dark sandy loam 1.5 to 5 feet deep, while around Sugar City it is a clay loam 4 to 6 feet deep. The land slopes to the south and west at the rate of about 10 feet to the mile.

At first ordinary ditches were built and for years attempts were made to irrigate the land by the usual methods. These failed, however, since all the water turned into the ditches soon sank into the porous subsoil beneath. In time much of this subsoil filled up with water, owing to an impervious lava bed rock, and the top layers of soil became moistened from below. This condition led the farmers to adopt a new method of irrigation, a type of which is shown in

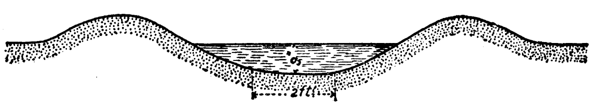

FIG. 35.—Supply ditch with bottom width of 2 feet.

Figure 36. On a farm of 120 acres, located 12 miles south of St. Anthony, Idaho, the main canal passes along the north and west boundaries. From this a supply ditch is run which feeds the smaller laterals. These laterals are shallow ditches about 3 feet wide and 6 inches deep and divide the farm into strips. On the majority of farms the laterals do not exceed 1,320 feet in length and are spaced 100 to 300 feet apart. On this particular farm their length is increased beyond the average and their width decreased. In this mode of irrigation no water is spread over the surface; the laterals merely distribute 15 to 20 miner's inches each to different parts of the field, where it soon joins the ground water by sinking through the bottoms of the shallow ditches. The land is planted in the early spring when the ground water is low, and then water is turned into the ditches and kept in day and night until the ground water rises sufficiently near the surface to supply the needed moisture to the roots of the plants. Thereafter the height of the ground water is regulated by the amount of water turned into the supply ditch. The rise and fall of the ground water is determined by means of small boxes set in the ground 3 to 5 feet deep, as indicated by the circles in Figure 36. Twenty to 30 boxes usually are required for each 80-acre farm. All water is turned out of the main canal prior to September 15 to permit the land to dry out for the harvesting of such crops as sugar beets, potatoes. etc. When the crops are removed, a small stream is left running in the main canal all winter; but notwithstanding this supply, the ground water usually falls from 6

to 20 feet below the surface during the fall and winter months. This somewhat novel method of applying water has led to the adoption of a rotation of crops which seems to suit both water and soil conditions. Alfalfa does not do well after the third year. This is due chiefly to the height at which the ground water is kept during the spring and summer months. Then, too, the soil is lacking in humus. These conditions have led the farmers to grow alfalfa on a tract for two or three years and then to turn the alfalfa under and raise grain,

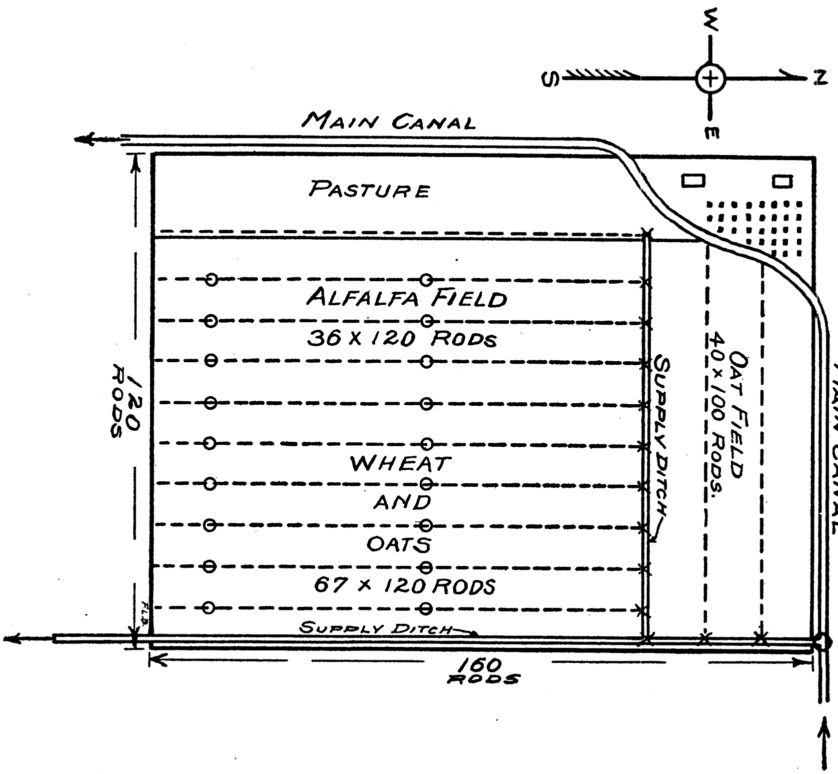

FIG. 36.—One hundred and twenty acre subirrigated farm 12 miles south of St. Anthony, Idaho.

sugar beets, and potatoes for the next three years. Under this rotation the yields per acre on well-managed farms are 40 to 60 bushels of wheat, 75 to 110 bushels of oats, 50 to 90 bushels of barley, 300 to 500 bushels of potatoes, 15 to 20 tons of beets, and 4 to 6 tons of alfalfa.

AMOUNT OF WATER REQUIRED.

Alfalfa requires more water than most crops. This is accounted for readily by the character of the plant, the rapidity with which it grows, the number of crops produced in one season, and the heavy tonnage obtained.

As a result of careless practice there is a lack of uniformity in the quantity of water used, the volumes applied frequently being far in excess of the needs of the crop. The majority of the records collected and published by this bureau show a yearly duty of water for alfalfa ranging from 2.5 to 4.5 feet in depth over the surface, while in quite a large number of cases the volumes applied would have covered the area irrigated to depths of 6 to 15 feet.

From the large number of measurements made on the duty of water it is possible to select some that possess considerable value, since they indicate what can be accomplished with a given quantity of water.

In 1903 the writer, when director of the Montana Experiment Station, applied different depths of water to seven plats of alfalfa with the results given in the following table. It will be seen that a high tonnage for so short a season as prevails in Montana was obtained from plat 5 with the use of 2 feet of water. By irrigating plat 6 seven times, and plat 7 eight times, it was possible to increase the yield to the amounts stated. The results of this experiment seem to confirm the best practice of other localities, which may be summed up by stating that in localities having an annual rainfall of about 12 inches remarkedly heavy yields of alfalfa may be obtained from the use of 24 to 30 inches of irrigation water, providing it is applied properly.

Quantities of water applied to alfalfa and yields secured, Montana Experiment Station.

Plat number.	Depth of irrigation.	Depth of rainfall.	Total depth.	Yield per acre of cured alfalfa.
	Feet.	*Feet.*	*Feet.*	*Tons.*
1	0.5	0.70	1.20	4.61
2	None.	.70	.70	1.95
3	1.0	.70	1.70	4.42
4	1.5	.70	2.20	3.75
5	2.0	.70	2.70	6.35
6	2.5	.70	3.20	7.20
7	3.0	.70	3.70	7.68

Studies of the use of water on alfalfa were made at Willows, Calif., by R. D. Robertson, of this bureau, during 1914 and 1915. The soil of the tract on which the experiment was conducted was a silty clay loam, grayish in color, of compact structure, and becoming hard when dry. The field was irrigated in borders and the slope of the ground was a little more than 0.3 foot per hundred feet. The following results were secured:

Irrigations per cutting.	Amount applied at each irrigation.	Number of cuttings.	Total yield.
	Inches.		
3	2	5	5.07
2	3	5	4.42
1	6	5	4.29

As a part of the cooperative irrigation investigations in California carried on by this bureau, the State department of engineering of California, and the California Agricultural Experiment Station a series of experiments was begun in 1910 at the university farm at Davis to determine the most economical duty of water for alfalfa in the Sacramento Valley. These were continued for a period of six years and were supplemented during the years 1913 to 1915, inclusive, by studies on a large number of representative alfalfa farms in the valley and also by experiments during 1915 on a temporary experimental plat near Willows. The results of these studies are embodied in Bulletin 3, State department of engineering, California, and Bulletin 280, Agricultural Experiment Station, California. The following tables are taken from these bulletins:

Summary of alfalfa duty-of-water investigations at Davis, 1910–1915.

Number of irrigations.	Unit depth each irrigation.	Depth of water applied.	Yield per acre.							Average value of hay per acre at $7 per ton.[1]	Average cost of production per acre.[2]	Average profit per acre.
			1910	1911	1912	1913	1914	1915	Average.			
	Inches.	*Inches.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*			
None	......	......	3.85	5.94	5.52	2.75	2.89	2.35	3.88	$27.16	$8.73	$18.43
Two	6	12	4.78	7.52	6.51	4.31	5.83	4.84	5.63	39.41	15.37	24.04
Three	6	18	......	......	7.02	5.69	8.02	6.46	6.80	47.60	19.35	28.25
Four	6	24	6.00	8.38	8.32	6.89	9.96	7.96	7.92	55.44	23.22	32.22
Four	7½	30	7.53	9.54	9.43	7.97	11.06	8.32	8.98	62.86	26.45	36.41
Four	9	36	7.58	9.33	9.38	8.22	12.48	8.63	9.27	64.89	27.96	36.93
Four	12	48	8.45	9.52	8.63	8.83	10.62	8.05	9.02	63.14	29.10	34.04
Four	15	60	......	......	10.17	7.25	10.70	5.55	8.42	58.94	29.44	29.50

[1] Market value of hay, 1910, 1911, and 1912, $11 per ton; 1913, $9; 1914, $4; 1915, $8.
[2] Labor of production, including cutting, raking, shocking, and hauling, figured at $2.25 per ton. Water figured at $1.70 per acre-foot. Labor for irrigation figured at $0.50 per acre per irrigation.

Summary of results of alfalfa duty-of-water measurements on 54 farms in Sacramento Valley, 1913 and 1914.

Name of area.	Average rainfall.	Number of fields included.	Areas covered by observations.	Years.	Average total depth of water applied.	Average total yield, per acre.
	Inches.		*Acres.*		*Feet.*	*Tons.*
Gridley	[1] 22.24	14	284.22	1913	3.31	6.19
Los Molinos	[2] 26.11	12	130.40	1913–14	5.15	6.01
Orland	19.23	7	214.52	1913–14	4.66	6.26
Willows	16.55	3	27.71	1914	1.83	4.82
Woodland	[3] 17.23	12	295.07	1913–14	2.33	6.45
Dixon	[3] 17.23	6	207.17	1913	2.94	6.76
Totals and averages	19.76	54	1,159.09	....	3.37	6.08

[1] Biggs record. [2] Red Bluff record. [3] Davis record.

Water was measured on a large number of fields of alfalfa in southern Idaho by Don H. Bark during the seasons of 1910 to 1913, inclusive. The results of these measurements are given in Department Bulletin 339, Experiments on the Economical Use of Irrigation Water in Idaho.

Experiments to determine the duty of water on 16 fields of alfalfa covering a wide range of soil and topography were made in Montana

by S. T. Harding during the summers of 1913 and 1914. The results of these experiments are summarized in the following table:

Water used on alfalfa fields in Montana, with yields.

Soil.	Average depth of water applied.	Average yield.
	Feet.	*Tons.*
Heavy types of soil	1.92	3.7
Medium types of soil	1.62	4.2
Light types of soil	2.14	4.2

Water was measured on more than 40 fields of alfalfa in Salt River Valley, Ariz., during 1914 and 1915. The results of a few of these measurements are given in the table below:

Water used on alfalfa fields in Arizona, with yields.

Soil.	Average depth of water applied.	Yield.
	Feet.	*Tons.*
Sandy loam	4.49	6.0
Adobe	3.54	8.0
Sandy loam	3.52	5.0
Do	4.25	6.5
Do	7.92	9.0
Do	2.29	2.8
Do	2.35	3.5

The following table, taken from Bulletin 117 of the Utah Agricultural Experiment Station, shows the effects on the yield of alfalfa of applying different quantities of irrigation water. The rainfall during the growing season, added to the moisture in the soil at the beginning of the season, amounted to 14.91 inches in depth over the surface.

Irrigation water applied (inches)	10.00	15.00	20.00	25.00	30.00	50.00
Yield per acre (tons)	4.94	3.77	4.55	4.67	4.42	5.41

The duty of water for alfalfa, as determined by C. E. Tait of this bureau, is shown by the depth of water used on seven tracts in 1905 and on six tracts in 1908 in various locations near Pomona, Calif., the water being pumped in all cases.

Water used on alfalfa tracts near Pomona, Calif.

Number of irrigations, 1905.	Depth applied by pumping.	Total including rainfall.	Number of irrigations, 1908.	Depth applied by pumping.	Total including rainfall.
	Feet.	*Feet.*		*Feet.*	*Feet.*
4	3.6	5.9	4	1.8	3.3
4	3.4	5.7	5	2.2	3.7
3	1.3	3.6	4	3.6	5.1
3	2.1	4.4	4	3.2	4.7
3	2.5	4.8	5	2.2	3.7
3	1.9	4.1	3	1.3	2.8
3	1.4	3.7	Average	2.4	3.9
Average	2.3	4.6			

In the Imperial Valley of southeastern California, where the rainfall is negligible, the depth applied by irrigation throughout the year averages 3½ feet for alfalfa.

PROPER TIME TO IRRIGATE ALFALFA.

The general appearance, and more particularly the color of the plant, are the best guides, perhaps, as to when water is needed. When healthy and vigorous, alfalfa is of a light-green color; but when the supply of moisture is insufficient the leaves take on a darker and duller shade of green and begin to droop, and unless water is provided both stems and leaves wither and die. Another test is to remove a handful of soil 6 inches or so beneath the surface and compress it in the hand. If it retains its ball-like shape after the pressure has been removed and shows the imprints of the fingers, the soil is sufficiently moist, but if it falls apart readily, it is too dry. In connection with such tests it is well to bear in mind that they are more or less influenced by both soil and climate. It is necessary therefore to observe the growth of the plant closely on all new alfalfa fields to determine if possible how far such tests may be relied upon, the chief object being to maintain at all times as nearly as practicable the proper amount of moisture in the soil surrounding the roots of the plants to prevent a checking of their growth.

Alfalfa commonly receives careless treatment at the hands of western irrigators. When water is available and is not needed for other crops it usually is turned on the alfalfa fields or meadows whether these need it or not. There is no question that yields of alfalfa might be increased considerably if more care were used in finding out when to apply water. In each kind of soil and under any given set of climatic conditions there is a certain soil moisture condition which will give the best results.

There is a considerable range between the moisture percentage at which the soil is too wet for a normal growth of the crop and that at which it is too dry. To use water most economically the limits of soil moisture percentages within which the crop grows best should be determined, and the practice adopted should be such as to keep the soil moisture within these limits at all times.

Under the present unskillful practice it is impossible to maintain uniform soil-moisture conditions for any length of time. The soil is likely to receive too much or too little water, or else it is deluged with cold water at a time when it needs only heat and air. The number of irrigations required depends upon the depth and nature of the soil, the method of applying water, the depth to ground water, the number of cuttings, and the rainfall, temperature, and wind movement. The number of irrigations and the time of irrigating depend to a considerable extent on the number of cuttings and the time of cutting. It is necessary to have the fields dry enough to permit the use of machinery for cutting the crop, and consequently they can not be irrigated just before cutting. But if light soils are not irrigated before cutting, they may not retain enough moisture to start the new crop and maintain its growth until the old crop is removed. Usually it is considered the best practice to irrigate as late as possible before cutting and irrigate again after the crop is removed if more water is needed.

Other things being equal, more frequent waterings are required in the warm sections of the Southwest than in the cooler portions of the North. The number of irrigations per year for alfalfa ranges from 4 in Montana and Wyoming to as many as 12 in parts of California and Arizona. In localities where water is scarce during part of the season the number of waterings as well as the amount used each time depend on the available supply. It is a common practice to apply frequent and heavy irrigations in spring when water is abundant and to water less often and more sparingly when the supply is low.

WINTER IRRIGATION OF ALFALFA.

When water is applied either to bare soil or to crops outside of the regular irrigation season it is termed winter irrigation. The practice thus far has been confined largely to the warmer parts of the arid region. It has become well established in Arizona and California and is being extended rapidly to parts of Oregon, Kansas, and the Rocky Mountain States.

Experience has shown that a deep retentive soil is capable of storing a large quantity of water. On account of the fluctuation of western streams of all kinds, from the small creek to the large river, the greatest flow of water often comes at a season when there is least demand for it. In a few localities adequate storage facilities have been provided to retain the surplus, but as a rule it is allowed to go to waste. The passage of so much waste water led to the introduction of winter irrigation and in nearly every case the results have been satisfactory. The chief differences between winter and ordinary irrigations are the larger volumes used, the crude manner of conveying and applying the water, and the dormant or partially dormant condition of the plants at the time of irrigation.

In Fresno County, Calif., water is turned into the canals in January and February. The large canals of the Modesto and Turlock districts run more than half a head during the latter half of February. This is the rainy period in both these localities and the soil usually is too wet for plant growth, but water is applied to alfalfa fields to fill up the subsoil so as to provide a surplus for the rainless summer when water is scarce.

Besides supplementing the supply of much-needed moisture, winter irrigation, when conditions are favorable, prevents winterkilling and improves the mechanical condition of the soil.

The midsummer irrigation of alfalfa is not generally practiced in many of the warmer districts of the Southwest, particularly in the Imperial Valley of California and the Salt River Valley of Arizona. The average annual yield of alfalfa in Imperial Valley is about 4½ tons per acre; but, owing to the growth of weeds, ravages of insects, silt, and hot weather, only about 3 per cent of the total yield is produced in September. Owing to the small midsummer yield of hay and its poor quality, farmers allow their alfalfa fields to dry out in August and September and apply water in winter or early spring.

IRRIGATING TO PREVENT WINTERKILLING OF ALFALFA.

The winterkilling of alfalfa is confined chiefly to the colder and more elevated portions of the Rocky Mountain region and to the northern belt of humid States. Damage from cold is rare in the

Salt River Valley in Arizona, and in California it is confined to young plants. In both the Sacramento and San Joaquin Valleys of the latter State the seed is frequently sown in midwinter and the slight frosts which occur occasionally in December and January in both these valleys are severe enough to kill very young plants. The belief is common that the plants are safe after they have put forth their third leaf.

In the colder portions of Montana, Wyoming, Colorado, Utah, and the Dakotas alfalfa is apparently winterkilled from a variety of causes and sometimes from a combination of causes. The percentage of loss around Greeley, Colo., has been placed at 2 per cent per annum. In this locality and throughout the Cache la Poudre Valley in northern Colorado most of the winterkilling is done in open, dry winters and generally is attributed to a scarcity of moisture in the soil. In the winter of 1907 considerable damage was done to the alfalfa fields around Loveland, Colo., by the long dry spell in midwinter. The old alfalfa fields suffered most. It was the opinion of the farmers that a late fall irrigation would have prevented the loss.

Near Wheatland, Wyo., the higher portions of the fields suffer most damage in winter, and here also the cause is said to be lack of moisture in the soil, combined with the effects produced by cold and wind.

At Choteau, in northern Montana, a farmer watered, late in the fall, part of an alfalfa field which was two years old, and it winterkilled, while the unwatered portion escaped injury. This and other evidence along the same line, which might be given, go far to demonstrate that under some conditions too much moisture is as detrimental as too little.

Probably the chief cause of the winterkilling of alfalfa is alternate freezing and thawing. The damage from this cause is greatly increased when any water is left standing on the surface. A blanket of snow is a protection, but when a thin sheet of ice forms over portions of a field the result is usually the death of the plants. The bad effects of alternate freezing and thawing on alfalfa may be observed at the edge of a snow bank. This crop is injured likewise by the rupture of the tap roots caused by the heaving of the soil.

During the winter of 1916–17 considerable winterkilling of alfalfa occurred in southern Alberta, Canada, particularly in the vicinity of Strathmore and Gleichen. During the winter of 1921–22 the loss sustained by winterkilling was greater and covered a larger area. The causes of winterkilling of alfalfa were investigated by the Reclamation Service of Canada, which reached the conclusion that the preventative measures to adopt consisted in (1) protecting the plants by a medium heavy growth of alfalfa and (2) in selecting hardy seed. Their investigations showed that when alfalfa fields were harvested or pastured late and allowed to go through the winter bare or nearly so, the plants winterkilled regardless of the moisture content of the soil or the variety of seed. On the other hand, when the moisture and other growing conditions permitted a late growth of sufficient height which was not cut, harvested, or pastured, there was no winterkilling. They also showed that Grimm and other hardy strains were much less liable to winterkilling. In most cases

a 6-inch covering gave complete protection to hardy varieties, whereas 12 inches were required for common varieties.

It may be stated in conclusion that the loss to the farmer from the winterkilling of alfalfa is not as great as might appear at first. The damage is done in winter, and there is ample time to plow the plants under and secure another crop, which usually is heavy, owing to the amount of fertilizer added by the roots of alfalfa. The Montana farmer who increased his average yield of oats from 50 to 103 bushels per acre by plowing under winterkilled alfalfa illustrated this point.

RISE OF GROUND WATER AND ITS EFFECTS ON ALFALFA.

In their natural state the typical soils of the arid region are characterized by the depth to water and their looseness and dryness. The diversion and use of large quantities of water in irrigation soon change some of these natural conditions. A part of the flow in earthen channels escapes by seepage and still larger quantities percolate into the subsoil from heavy surface irrigations. The waste water from these and other sources collects in time at the lower levels and raises the ground-water level. Usually this rise is noticed first in wells, a permanent rise of 5 feet in a year being not uncommon.

This rise of the ground water is an advantage, provided the water table does not rise too high. It lessens greatly the cost of sinking wells, less water is needed in irrigation, and it furnishes a reservoir from which water can be pumped to supply other lands.

It is not until the water level encroaches upon the feeding zone of valuable plants that its injurious effects are felt by the farmer. Its near approach to the surface may prove so disastrous that its upward trend should be noted with the greatest care. Perhaps the best means of providing for such observations is the use of test wells, referred to on page 26.

There is some difference of opinion as to what depth below the surface marks the danger line for alfalfa. It has been shown by Doctor Loughridge, of the University of California, and by other soil physicists, that water may be withdrawn by capillarity from saturated soils to depths varying from 4 to nearly 5 feet, depending on the character of the soil. This fact has an important bearing on the subject, because when the ground water is brought to the surface and evaporated the salts held in solution are deposited at or near the surface. If these salts contain much sodium sulphate, or even sodium chlorid, which are usually grouped under the common term alkali, the crust formed by them will in time destroy the alfalfa. It may be stated, therefore, that when alkali is present in harmful quantities in the ground water it should not be allowed to rise nearer than 4 feet of the surface.

The percentage of harmful salts in the ground water is determined usually by the chemist of the nearest agricultural experiment station, but when an accurate test can not be made in the laboratory the farmer may make a practical test in the following manner, in accordance with a suggestion made by A. T. Sweet, of the Bureau of Soils of this department:

Take three pots containing equal amounts of soil and plant the same number of grains of wheat in each. Water each pot with equal

quantities of water. In No. 1 apply fresh water, in No. 3 ground water, and in No. 2 an equal amount of each kind. The injury, if any, caused by the ground water will be indicated by the longer time required for the plants to appear above the surface, the smaller number of plants to germinate, and their general appearance.

In soils free from alkali but saturated with water there is not the same necessity for holding the ground water continuously below a so-called danger line. In parts of Kern County, Calif., the ground water sinks to 8 feet below the surface of alfalfa fields in summer, but rises to within 1.5 feet of the surface in winter. There is no indication of root rot and the plants have retained their full vigor. Numerous cases might be cited to show that the rise of water to within a foot or two of the surface for comparatively short periods of time does little injury to the plants. On the other hand, wherever water stands continuously during the irrigation season within a few feet of the surface it is pretty certain to kill alfalfa in three years or less.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE.

August 25, 1925.

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